The Open University

S103 discovering science

S103 SG9

Note that the times shown in the study plan overleaf do not include the time that you will need to answer questions on the DVD and the TMA, making use of the set book, watching the TV programme, attending sessions at your local or regional centre or reflecting on what you have learned and how you have learned it. Past students have also commented that *our* estimates of the times needed for the study of the DVD-multimedia activities are likely to be low.

Study Guide for Block 9

Block 9 returns to the study of living organisms. We start with a review of cell structure and go on to investigate the molecular components and chemical reactions that are common to all living cells. We then examine how information is passed down from generation to generation, and look at the molecules involved in inheritance by examining genes, which link generations through their continuity. Finally, we consider long-term ancestry — the process of evolution, which involves genetic change over time.

This block represents four weeks' work. The study plan overleaf shows how you might divide your time over the four study weeks. However, if you have chosen to omit study of either Block 10 or Block 11 you may wish to spend a little more time on Block 9. As well as studying the printed material, you will study a DVD-video sequence and a TV programme, and work with four DVD-multimedia activities, one of which has practical work associated with it. In Block 4 you were introduced to the practical work with the holly leaf miner, and we asked you to locate a holly bush or tree that showed evidence of this insect. During your study of this block, you will need to collect about 40 leaves, each of which contains a mine produced by the larval stage of this insect. To investigate the mines, you will require a sharp knife, a large sewing needle and your hand lens. You can do this practical work and study the related DVD-multimedia activity ('Holly leaf miner') at any time during your study of this block. Another DVD-multimedia activity ('Cells and energy') comprises almost the whole of Section 7 and revises principles from earlier in the block. The DVD-multimedia activity in Section 8 ('Mitosis, meiosis and recombination') is particularly important because it introduces material not covered in the book. Towards the end of the block you will complete your study of the 'Galapagos' DVD-multimedia activity, which you began during your study of Block 4.

Many of the activities in Block 9 focus on the skill of revising. You will be asked to revise concepts from earlier parts of the course that are needed for this block — in particular, concepts from Blocks 4 and 8 — and to write summary paragraphs, produce tables and draw flow diagrams of concepts in this block, all of which can be used for revision purposes. In addition, you will be asked to criticize answers to assignments, to mark both your own answers and those of other students, and to plan and write a longer scientific account. Some of these activities, which are designed to improve your written answers, may take a long time to complete. However, you will learn a lot by doing them, and this will help you when answering questions in subsequent assignments.

We recommend that you study the various sections of this block — with the exception of the holly leaf miner activity (Activity 1.1) — in the order in which they are presented, since several sections build on material covered in earlier sections. This is particularly important for the DVD-multimedia activity 'Mitosis, meiosis and recombination' which you should study at the end of Section 8, since an understanding of the content is needed in order to follow Section 9. If you are unable to tackle this activity at the recommended time, then we suggest that you jump to Sections 10 and 11 of the book, and come back to Section 9 after completing the Section 8 DVD-multimedia activity, and before studying Section 12.

The study plan overleaf indicates how the sections could be divided between four study weeks. The total study time for the block is just over 40 hours, but you will need to allocate additional time for collecting holly leaves, for answering the DVD questions, for using the set book (*SGSG*), for viewing the TV programme, and for meetings at your local or regional centre or of a self-help group. You will also need to allocate time to the TMA questions for Block 9, which form TMA 07.

The *Study Calendar* gives you the broadcast times of the relevant TV programme 'Sickle cell disease: a lethal advantage'. We recommend that you watch this programme at the end of Section 13, if possible.

You should start your study of Block 9 by reading Section 1 of the book.

Copyright © 2004 The Open University
5.1 DS

SUP 83618 9

9 Continuity and change

All study times are in hours

Week	Sections of Book 9	Total study time	DVD-multimedia, DVD-video and practical activities
1	1 Introduction	2 3/4	multimedia 🔍 2 1/2
	2 Cells	1 1/2	
	3 The chemistry of life: introducing biological molecules	4	
2	4 Basic principles of metabolism	3	
	5 Glucose oxidation	4	
	6 Photosynthesis	1	
	7 Energy in cells: a review	1 1/2	multimedia 1 1/2
3	8 Meiosis and the genetic lottery	4 3/4	multimedia 1 3/4
	9 Variations on a gene	2	
	10 What are genes made of?	3	
4	11 Using genetic information	4 1/2	video 1/2
	12 Looking at genomes	1 1/2	
	13 Evolution by natural selection revisited	4	
	14 Natural selection and speciation	4	multimedia 2
	15 Levels of explanation reviewed	1	

'Sickle cell disease: a lethal advantage' should be viewed during your study of Section 13. 📺

Printed in the United Kingdom by
City Print (Milton Keynes) Ltd.

The Open University

S103 discovering science

Study File for Block 9

Contents

Notes on activities 1

Comments on activities 24

Objectives for Block 9 41

Appendix What to do if you are short of time 44

Notes on activities

You should read through the notes for each activity before attempting it. After completing an activity you should study the relevant comments in the next section of the Study File.

No estimate of time is given for activities that should take 10 minutes or less.

Activity 1.1 Quantifying mortality factors in the holly leaf miner: Part 2

(The estimated time for this activity is 2½ hours split into two sessions, the first of about 30 minutes, the second of about 2 hours. This excludes the time you will spend collecting holly leaves.)

Equipment

KIT ITEM
Hand lens

NON-KIT ITEMS
Plastic bag and sealing tag
Clean knife with a small sharp blade (e.g. scalpel, kitchen knife or penknife)
40 mined holly leaves
Tweezers
Desk lamp (optional)
Large needle, e.g. darning needle (optional)
Chopping board (optional)

Aims

1 To carry out a biological project involving field work.

2 To identify some of the mortality factors that operate at different stages of an organism's life cycle and calculate their relative magnitudes.

3 To identify the key mortality factor and a regulating mortality factor, and explain how a regulating mortality factor operates in a density dependent way.

4 To explain how knowledge about various mortality factors can be used when devising means for the biological control of pest species.

Introduction

In Block 4 you were asked to locate a holly bush that showed evidence of holly leaf miner activity. Since then, the holly leaf miner adults that survived the larval and pupal stages have emerged from the leaves, completing the life cycle for this year, and it is now time for you to continue your practical work on this species.

Planning and procedure

The order in which you should tackle this activity is as follows:

1 (*30 minutes*) Study Sections 1–3 of the DVD-multimedia activity 'Holly leaf miner'. This explains the biology of the holly leaf miner and its predators, and shows you how to start the practical work.

Copyright © 2004 The Open University

SUP 83611 0

5.1 DS

2 (*no time allowance*) Collect your sample of 40 holly leaves from a holly bush or tree, any time after the end of June (though if you live in the north, you may be better to wait until at least mid-July because adult emergence occurs later in cooler climates). Once you have collected the leaves, they can be put in a polythene bag, sealed with a tag and stored in a fridge until you are ready to analyse them. They can be stored in this way for a maximum of 6 days, though the sooner you analyse them the better. If you can't find a holly bush with mined leaves, contact your tutor for help. Other students in your area may also be able to give you advice about the location of suitably mined bushes.

3 (*1 hour for studying the DVD-ROM and 1 hour for examining and dissecting your own sample of mined leaves, i.e. a total of 2 hours*) Study Sections 4–7 of the DVD-multimedia activity 'Holly leaf miner' as soon as possible after collecting the leaves.

In this session:

(a) You will be shown how to complete the practical work.

(b) You will examine and dissect the leaves, and then record and analyse your data.

(c) You will compare your own data with a larger data set collected from a specific pair of holly bushes over several previous years by students taking an earlier version of this course. By analysing this larger set of data, you will investigate population processes in a way that is not possible with a single-year sample of mined leaves.

Safety precautions

(a) When collecting leaves, you may wish to wear gloves to protect your hands from being scratched by the pointed leaves.

(b) This activity requires you to dissect the holly leaves using a sharp knife, so you should take care not to cut yourself. Use a clean knife to carry out the dissections so that, if you do happen to cut yourself, the risk of infection is minimized. If you do cut yourself, rinse the cut with clean water. If the cut is serious, try to reduce the blood flow by putting a pad of *clean* tissue or cloth over the wound and pressing gently, but firmly, until the flow stops. If you have any concerns, seek medical aid immediately.

(c) You should keep the holly leaves away from food (e.g. if you preserve them in the fridge, after collecting and before analysing them, make sure you seal them in a plastic bag; do not allow them to come into contact with food on kitchen work surfaces, etc.)

(d) When you have finished working with the leaves, wash your hands, any equipment used during the activity and any work surfaces they have come into contact with.

Additional terms used in this activity that are not in the glossary

You are not expected to be able to explain these terms.

leaf abscission	The loss of a leaf from a plant and which is under the control of the plant.
biological control	The deliberate introduction of an organism that is a predator or parasite of a pest species.
fecundity rate	The number of fertilized eggs per individual produced on average in a population.
ovipositor	The egg-laying structure of an insect.

(NB the words underlined in the definitions above appear in the *Course Glossary*.)

'Holly leaf miner' is on the Block 9 DVD-ROM.

Activity 2.1 Revision: cells and classification of organisms

This is the first of a number of activities designed to help you revise material from earlier in the course, an understanding of which you will require in order to follow particular sections of this block. Revision, like learning, is an active process. These revision activities will help you to recall key points and will help you organize and condense large amounts of information.

Block 4 introduced you to a simple classification of the living world in which all organisms were divided into domains and kingdoms. This activity revises the key features of this classification. Complete Table 2.1.1 by filling in the blank spaces with the characteristics of the various domains and kingdoms. Try to complete as much of the table as possible before you check back to Block 4, Section 4. If you are unsure of the meaning of the column headings, then you should check the definitions of these terms in the Course Glossary before completing the table.

Table 2.1.1 Characteristics of the domains and kingdoms.

Domain/kingdom	Unicellular or multicellular	Eukaryotes or prokaryotes	Autotrophs or heterotrophs
domain Archaea			
domain Bacteria			
kingdom Animalia			
kingdom Fungi			
kingdom Plantae			
kingdom Protoctista			

The comments on this activity include hints about integrating information from different parts of the course, and about revising.

Activity 3.1 Revision: chemical compounds

This is the second of a number of activities designed to help you revise material from earlier in the course. It refers back to Block 8, which we recommended very strongly that you should not omit as part of your study. Try to complete the activity before you check back to Block 8, Sections 10–16.

For each item in the list given below, write a sentence that defines what the item is, and give an example.

carboxylic acid, amine, amino acid, catalyst, enzyme, condensation reaction, covalent bond, ester, hydrolysis, monomer, polymer.

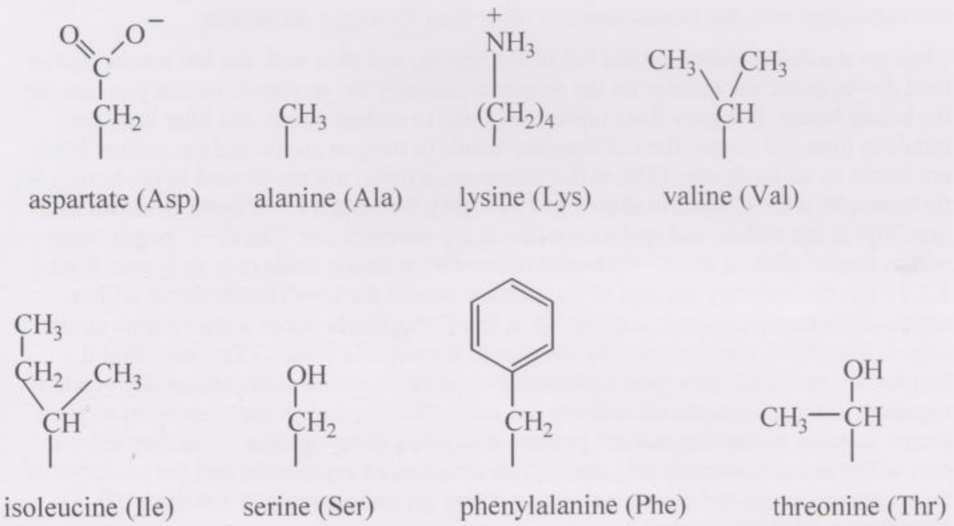
The comments on this activity include a few more hints about revising.

Activity 3.2 Revision: weak bonds

The purpose of this activity is to revise your understanding of the three types of weak bonds, all of which play a role in forming and maintaining the higher-order structure of proteins. Each amino acid has a different R group — the group that sticks out from a polypeptide chain and is free to interact with other R groups after the peptide bonds have been formed between the carboxylic acid group of one amino acid and the amino group of the next amino acid. The R groups of eight amino acids are given in Figure 3.2.1.

(a) For each R group, identify which of the other seven R groups it could interact with, and name each type of interaction.

(b) If each of these amino acids occurred in the same protein in a cell, identify where the R groups would be found in relation to the structure of the protein molecule as a whole.



aspartate (Asp) alanine (Ala) lysine (Lys) valine (Val)

isoleucine (Ile) serine (Ser) phenylalanine (Phe) threonine (Thr)

Figure 3.2.1 The R groups of eight amino acids.

Activity 3.3 From amino acid sequence to functional protein

(The estimated time for this activity is 30 minutes.)

This activity also refers back to Block 8. It will help you understand and remember how the primary structure of a protein determines its higher-order structure. It is the first of a number of activities in this block that require you to do some writing in order to develop your writing skills for answering assignment questions. Later activities will require you to mark either your own answers or those of other students, and this will involve you in developing the skill of being critical which, in turn, you can apply to your own written work.

Assume that you have had a letter from a fellow student, Sam, who cannot see how *a particular primary structure of a specific globular protein determines its higher-order structure*. Your task is to explain this, and you can refer to particular figures in the book rather than draw your own here. Your friend doesn't know about biopolymers in living organisms, but understands different functional groups and the structure of polymers as presented in Block 8. Try to respond to him in about 300 words.

We suggest that you close the book before writing your explanation, and then look at the relevant pages of the book and amend your answer.

multimedia

Activity 3.4 Viewing biological molecules using WebLab

(We recommend that you spend about 15 minutes on this activity.)

This activity uses the WebLab Viewer to look at biological molecules in three dimensions. It assumes that you know how to use the Viewer, instructions for which were given in Block 8, Activity 12.2. You may have already looked at some of the molecules on the Block 9 DVD-ROM (glucose, glycogen, cellulose, a TAG and a phospholipid) using WebLab, whilst studying Section 3 of this block. (If you have not already done this, now would be a good time to do so.) These molecules are much bigger than the organic molecules that you looked at using the WebLab Viewer in Block 8. Whilst normal ball and stick representations work well with most small to medium-sized molecules, things start to get more complex when we view proteins, which may contain many thousands of atoms. In this activity you will explore a number of other structural representations that are useful for visualizing two proteins, myoglobin and trypsin.

You should start this activity by first placing DVD 2 in your computer and then opening the WebLab Viewer from the S103 Discovering Science folder on the Programs menu of the Start button.

(a) Viewing the structure of myoglobin

Once WebLab is running, open the file named 'myoglob'. You will find this in the MOLECULE folder on the DVD. The protein myoglobin is a biopolymer that is made from amino acid monomers, and it is coiled up rather like a ball of string. The structure, a so-called *framework representation* of myoglobin, will appear. In a framework representation only the bonds to atoms other than hydrogen are shown.

Click on the Zoom button on the left of the screen, and then with the left mouse button held down, move the pointer up the screen to magnify the molecule so that you can see the bonds better. The grey lines represent bonds to carbon atoms, the blue lines are bonds to nitrogen atoms, the red lines are bonds to oxygen atoms and the yellow lines are bonds to sulfur atoms. (The sulfur atoms are a detail not mentioned in the book.) So, for example, a $\mathrm{C{-}C}$ bond is shown just as a grey line, but a $\mathrm{C{-}N}$ bond is shown as a grey line at the carbon end and a blue line at the nitrogen end. The $\mathrm{C{-}C}$ bonds occur within amino acids; a few $\mathrm{C{-}N}$ bonds occur within amino acids (e.g. in lysine, Figure 3.2.1), but the majority are part of the peptide bonds; the $\mathrm{C{-}O}$ bonds occur within amino acids (e.g. in serine); and finally, a few $\mathrm{C{=}O}$ bonds occur within amino acids (e.g. in aspartate), but the majority are part of the peptide bonds. (You may find it helpful to look at the structural representation of three amino acids covalently bonded together, in the comments on Activity 3.1 on p. 25.) The red crosses represent oxygen atoms in water molecules that are present in crystals of myoglobin — so they are not part of the myoglobin molecule itself. (The structure of myoglobin and the positions of these oxygen atoms are determined using X-ray crystallography — see the S103 TV programme 'Hidden visions'.)

To show the atoms more clearly:

- Click on the Display Style button at the top of the screen (the one with the red and white water molecule icon);
- Click on Ball and Stick from the list of Display Styles in the tabbed dialogue box;
- Click on OK.

Though the atoms are clearer in the ball and stick model, the atoms and bonds at the front tend to obscure those behind them. Rotate the molecule to get a better idea of its structure, and notice how it looks like a ball of string. Take the molecule back to its normal size by clicking on the Fit to Screen button at the top of the screen.

The complex shape of myoglobin is important and all molecules of myoglobin have the same convoluted structure. There are many special facilities in WebLab for viewing protein molecules, which help us to understand how the protein is folded, but we will introduce just a few of them in this activity.

To look at a simpler representation of the myoglobin molecule:

- Click on the Display Style button;
- Click on Off in the list of Display Styles on the Atom page;
- Bring the page titled Protein to the front by clicking on its tab;
- Next click on Ca Stick from the list of Display Styles;
- Click on OK.

In this representation, the sequence of colours effectively represents the sequence of amino acid monomer units in the polypeptide chain. Rotate the molecule to get a better idea of how the chain folds. You should be able to follow the chain from the N-terminus — a green stick, through to the C-terminus — a white stick.

An even more simplified representation of the higher-order structure can be obtained:

- Click on the Display Style button;
- Click on Flat Ribbon from the list of Display Styles on the Protein page;
- Click on OK.

The protein chain is now represented as a ribbon. The colours still reflect the sequence of amino acid monomer units in the polypeptide chain, but the regular spiral structure of portions of the polypetide chain is now clearer.

This higher-order structure can be emphasized even more:

- Click on the Display Style button;
- Click on the down arrow beside the Colour Scheme drop-down list box.
- From the options in that list, click on By Secondary Type;
- Click on OK.

Each red spiral, or helix (plural: helices), in this representation of myoglobin is a portion of the polypeptide chain that spirals regularly to make a rigid cylinder. This type of helical structure is one of a number of structural patterns that recur repeatedly in proteins. In the myoglobin molecule, you can see how the red helices are interspersed with irregular folding patterns of the polypeptide chain (white), to produce the highly specific structure needed for a specific biological function.

Many proteins require a bound specific non-protein group for their biological activity. Myoglobin contains such a group (see Figure 3.5 in the book), the *haem* group, which consists of an organic part and an iron atom to which oxygen binds. The iron required to synthesize this haem group is obtained from food. To highlight the haem group:

- Click on the Display Style button;
- Click on Off in the list of Display Styles on the Protein page;
- Now bring the Atom page to the front by clicking on its tab;
- Click on Line from the list of Display Styles;
- Click on the arrow beside the Colour Scheme box;

- Click on the Chain option from the list that is displayed;
- Click on OK.

Most of the molecule turns white, except for the orange haem group, which is located in a crevice in the middle of the myoglobin molecule. Zoom in on this orange group and then rotate the molecule so that you can see its position in the molecule.

Now select Close from the File menu to remove the myoglobin structure. Do not save any changes.

(b) Viewing the structure of trypsin

The trypsin molecule is an enzyme that breaks down food proteins in the gut. Open the file named 'trypsin' from the MOLECULE folder on the DVD, and rotate the molecule to examine its structure. Again you can see the 'ball of string' structure characteristic of globular proteins, and the grey, red and blue bonds, as you saw for myoglobin. (You may also notice a set of green bonds to a calcium atom. This detail is not mentioned in the book.)

Now look at the size of the active site of this enzyme:

- Click on the Display Style button;
- Click on the arrow by the Colour Scheme box on the Atom page;
- Select the Chain option from the list that is displayed;
- Click on OK.

Most of the molecule is now white but you should be able to see one blue molecule. (There are also a few oxygen atoms in water molecules shown in red.) This small blue molecule (similar in shape to the substrate) is occupying the active site in trypsin and is held there by weak bonds between it and the enzyme molecule. The weak bonds are not shown, so the blue molecule appears not to be attached to the trypsin molecule. The active site is only a small part of the enzyme and is difficult to see. If you enlarge and rotate the blue molecule you may be able to see that it fits into a cleft on the surface of the enzyme — this is the active site.

We will now examine the higher-order structure of trypsin.

- Return the trypsin molecule to normal size by clicking on the Fit to Screen button at the top of the screen;
- Rotate the molecule to place the active site in a position where you can easily see it;
- Click on the Display Style button;
- Bring the Protein page to the front by clicking on its tab;
- Select Flat Ribbon from the Display Styles;
- Select the By Secondary Type option from the Colour Scheme box;
- Click on OK.

This way of displaying the structure reveals two red portions where the polypeptide is wound into regular helices, a structural pattern you saw in the myoglobin molecule. Another structural pattern that regularly occurs in proteins can be seen in this view of trypsin. It is shown in blue and consists of a sandwich-like structure of parallel sheets, in which the polypeptide chain is folded over itself. Again, notice how the regular portions of the polypeptide chain (red helices and blue sheets) are interspersed with irregularly folded portions of the polypeptide chain (white). The complete structure provides the specificity between the enzyme and its substrate.

When you have finished looking at the trypsin molecule, you should close the trypsin file using the Close option from the File menu, without saving any changes.

Activity 4.1 Revision: reactions rates, and oxidation and reduction

The purpose of this activity, again based on Block 8, is to revise concepts about chemical reactions. Try to answer before checking back to Block 8, Sections 10 and 14.

(a) In order for a reaction to occur, the reactant molecules must encounter each other. Write a short sentence to explain why each of the following three changes increases the rate of a chemical reaction in a test-tube: (i) increasing the concentration of reactants; (ii) increasing the temperature; (iii) adding a catalyst.

(b) (i) Equation 4.1.1 (which is unbalanced) shows the conversion of one organic compound to another. Explain, in one sentence, what kind of reaction it is.

$$CH_3{-}CH_2{-}COOH \longrightarrow CH_3{-}CO{-}COOH \qquad (4.1.1)$$

(ii) Explain also what kind of reaction the reverse reaction to Equation 4.1.1 is.

Activity 5.1 Producing a summary diagram of glucose oxidation

(The estimated time for this activity is about 20 minutes, divided into a number of chunks. If you do it whilst studying the related sections of text it will take very little time.)

In addition to the revision activities, which are designed to help you revise material from earlier in the course, many activities in this block require you to condense whole sections of text into a few paragraphs or into a diagram. The answers to both types of activity will be useful aids in revising before going on to higher level studies. Remember that to benefit from these activities you need to produce your own answers, since this will involve you in thinking harder about the subject.

Figure 5.1.1 (*overleaf*) is a copy of Figure 5.1 in the book, which shows the pathway of glucose oxidation in the cell. This figure provides a framework of the overall pathway for you to refer to whilst studying Sections 5.2–5.5. In this activity you will produce your own summary diagram by adding information to Figure 5.1.1, such as the relevant bold terms and the main reactions. This will enable you to see how the details — the molecules and reactions — relate to the overall scheme of things. Such a diagram will also be useful for reference whilst you review glucose oxidation in the DVD-multimedia activity (Activity 7.1). It is a good idea to add information to your summary diagram after completing each subsection. We suggest you use pencil when adding information so that if the diagram gets cluttered you can easily change it.

Begin by adding information shown in Figure 5.2 to your summary diagram. Keep your summary diagram readily available so that you can both add details to it and refer to it as you study Sections 5.2–5.5.

After studying each of Sections 5.2–5.4

If you have not already done so, add the important details, such as the relevant bold terms and the key reactions that were described in this section, to your summary diagram. You may need to refer back to the text to help you with this.

After studying Section 5.5

First add the important terms and reactions described in Section 5.5, including 'anaerobic respiration'. This completes the information to be added to your summary diagram, but before leaving this activity you should review your completed diagram. We took care to ensure that the information we added was clearly shown and did not clutter our diagram. You should look at your own version and make sure that it is clear, and if necessary amend the layout. You also need to check that you will still be able to understand it in a few weeks time. For example, if you have used abbreviations have you added a key to show what these represent?

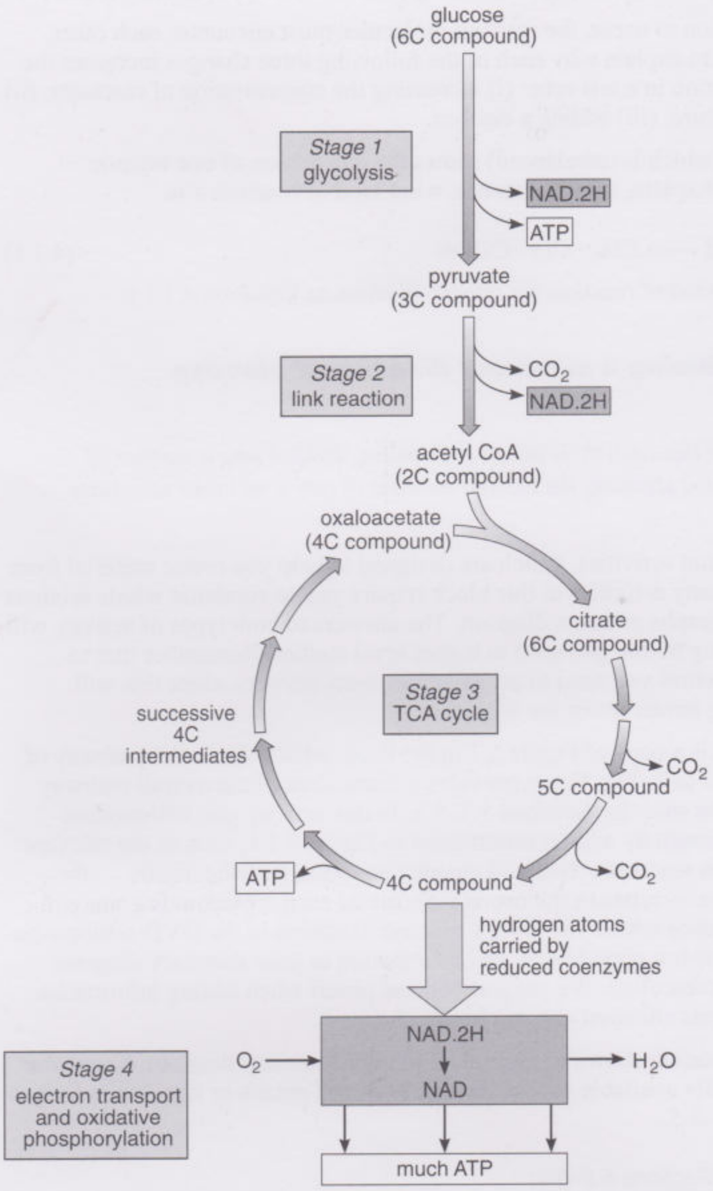

glucose
(6C compound)
Stage 1
glycolysis
NAD.2H
ATP
pyruvate
(3C compound)
Stage 2
link reaction
CO_2
NAD.2H
acetyl CoA
(2C compound)
oxaloacetate
(4C compound)
citrate
(6C compound)
Stage 3
TCA cycle
successive
4C
intermediates
CO_2
5C compound
CO_2
ATP
4C compound
hydrogen atoms
carried by
reduced coenzymes
Stage 4
electron transport
and oxidative
phosphorylation
O_2
NAD.2H
NAD
H_2O
much ATP

Figure 5.1.1 The glucose oxidation pathway showing the four distinct stages. This is a copy of Figure 5.1 in the book.

Activity 5.2 The 'power-house of the cell'

(The estimated time for this activity is 20 minutes.)

The stages of glucose oxidation that occur in the mitochondria are not straightforward, and Stage 4 in particular — electron transport coupled to oxidative phosphorylation — is quite complicated! In order to help your understanding of the reactions that occur in the mitochondria, including the coupling of the reactions that take place at the inner mitochondrial membrane, draw a flow diagram to summarize the steps by which the energy stored in pyruvate is transformed into energy stored in ATP. Your diagram should include production of reduced coenzymes, and the steps by which the energy stored in these coenzymes is transferred to ATP.

First see how far you can get without reference to the book or to the summary diagram you produced in Activity 5.1. Then complete your flow diagram by referring to your summary diagram and checking the book for further details.

Activity 7.1 Cells and energy

multimedia

(The study time allocation for this activity is 1½ hours.)

A combination of animations, graphics and questions in this DVD-multimedia activity reviews the structure and function of organelles found in cells, takes you through the stages of glucose oxidation and then the reactions of photosynthesis, and makes them come alive in a way that is not possible in a book.

When studying the animation of glucose oxidation, you will find it helpful to have to hand the summary diagram of glucose oxidation that you completed in Activity 5.1. Here the number of steps in the pathway of glucose oxidation is reduced to 13, and the number of steps in photosynthesis is reduced to 8. Some information additional to that provided in the text is incorporated in various parts of this activity, but you are not expected to remember this and won't be assessed on it. This enrichment is included in order to portray the reactions accurately in the animation, and to enhance understanding.

We estimate that it may take more than the time allocated to complete all three parts of this activity. Therefore, we suggest that you study the short review of organelles fairly quickly, and then concentrate on the pathway of glucose oxidation, paying particular attention to any steps that you have not understood in the text, and *study the photosynthesis exercise only if you have time*. When studying photosynthesis, concentrate in particular on the similarities and differences between this process and glucose oxidation.

You should read the notes below before you start the photosynthesis exercise.

'Cells and energy' is on the Block 9 DVD. You should start this activity now.

Additional information about photosynthesis and terms used in this activity

You are not expected to be able to explain the italicized terms.

The structure of the chloroplast and the reactions occurring inside it are more complex than described in the book. Before studying the relevant part of this activity, you may find it helpful to read the text below in which three terms used in the activity (but not included in the glossary) are defined and the role they play in photosynthesis explained.

A *thylakoid* is a flattened sac of the innermost membrane of the chloroplast. A pile of thylakoids is referred to as a granum (plural: grana). Inside each thylakoid is a space, the *thylakoid lumen.*

When water is split, releasing oxygen, the protons are released and the electrons are passed along the photosynthetic electron transport chain. NADP, present in the stroma, is reduced to NADP.2H by combining with the electrons, and protons from the stroma. Three of the carriers in the electron transport chain in the thylakoid membrane are proton pumps and transport protons from the stroma into the thylakoid lumen, forming a proton gradient. Protons flow back, down their concentration gradient, from the thylakoid lumen through the channel in the ATP synthase enzyme, back into the stroma. The energy released from this flow of protons is used to synthesize ATP from ADP and P_i.

There are actually *two* membranes that surround the chloroplast. The first carbon compound to be produced in the chloroplast is a 3C sugar phosphate; this is transferred to the cytosol by a specific transport protein situated in the inner of these two membranes. This transfer is quite complex and involves the movement of an inorganic phosphate ion (P_i) into the chloroplast in exchange for each 3C sugar phosphate molecule entering the cytosol. This exchange process is called *phosphate translocation.*

Activity 8.1 Revision: chromosomes and the life cycle

(The estimated time for this activity is 25 minutes.)

This activity will help you to revise what you learnt in Block 4 about the life cycle and changes in chromosome number. You will also improve the writing skills that you use for answering assignment questions, by making a critical assessment of a piece of written work. As Block 9 progresses, we will ask you to move from being critical of someone else's work to being critical of your own. As the first step in this process, this activity asks you to imagine that you are a tutor and to mark a piece of work submitted by a student who has just finished reading Block 4, Section 6. You are not required to do any writing yourself.

(a) First look at the question that the student has been asked to answer:

Describe the stages in a life cycle, such as the human life cycle, and indicate the changes in chromosome number at each stage. Your explanation should include a labelled diagram and should be no longer than 250 words. You should include, and show good understanding of, the following terms: autosome(s), centromere, chromatid, chromosome, diploid, fertilization, gamete, haploid, meiosis, mitosis, nucleus, ovum, sex chromosomes, zygote. *(25 marks)*

(b) Next look at the student's answer and mark it against the mark scheme below. To do this you will need to identify the scientific errors/omissions, judge the suitability and labelling of the diagram and judge the quality of the writing. The best order to do this is:

1 Read the answer.

2 Familiarize yourself with the mark scheme.

3 Re-read the student's answer, awarding marks as you do so.

Student's answer

Haploid cells contain one set of chromosomes and diploid cells contain two sets, with each chromosome (usually) having a morphologically identical partner. The sex chromosomes — usually called autosomes — form a pair. Chromosomes are tiny threadlike structures that occur free in the nucleus of each cell. For part of the cell cycle, individual chromosomes are single-stranded, but by the beginning of meiosis they are double-stranded. Each strand is called a chromatid and the two strands are held together at the centromere. Haploid cells contain one set of chromosomes and diploid cells contain two sets.

Adult animals and plants are diploid, with very few exceptions. No species of eukaryote that reproduces sexually is composed entirely of haploid or entirely of diploid cells at all stages of its life cycle. The alternation of these two types of cells within the life cycles of organisms is shown in the diagram.

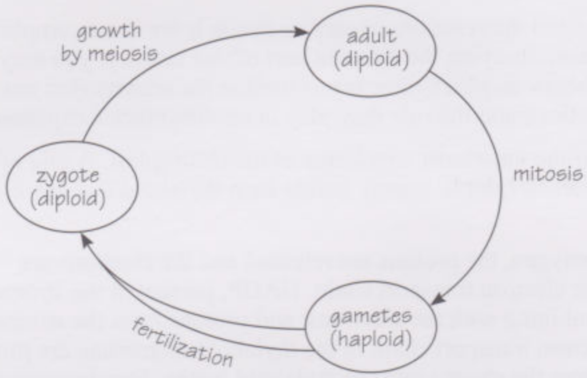


Figure 8.1.1 (Student's diagram. Note the diagram contains errors!)

The production of haploid gametes is brought about by the process called mitosis. The zygote divides by means of meiosis to produce an adult organism. Meiosis occurs as a series of stages, named prophase, metaphase, anaphase and telophase. Each cell of the adult, other than the reproductive cells, contains identical copies of the genetic material. *(202 words)*

Mark scheme

Award one mark each for *correct* use of each of the required terms: autosome(s), centromere, chromatid, chromosome, diploid, fertilization, gamete, haploid, meiosis, mitosis, nucleus, ovum, sex chromosomes, zygote.	*14 marks*
Award two marks for correct description (in the text or in the diagram) of the changes of chromosome number.	*2 marks*
Award two marks for the diagram, plus one mark for labelling and one for the title	*4 marks*
Award five marks for quality of writing, broken down as follows:	
Clarity of writing (deduct one mark for each ambiguity);	*2 marks*
Conciseness (deduct one mark for each irrelevant point and for any repetition);	*2 marks*
Coherence — writing with a logical flow.	*1 mark*
Total marks	**25 marks**

Award marks for the student's answer, and then check the mark you gave with those awarded by an S103 tutor in the comments on this activity.

Activity 8.2 Tackling problems in genetics

(The estimated time for this activity is 25 minutes.)

General hints for tackling problems in genetics

In Blocks 5 and 8 you were encouraged to develop strategies for solving different sorts of problems. Here we will offer some guidelines on how to set about solving genetics problems, and you will then tackle a problem using these guidelines. You need to bear in mind that genetics problems cannot be solved by rote learning; each one has to be tackled afresh using your understanding of genetic principles, common sense, and sometimes trial and error. Here is a list of guidelines, which should help you to tackle a wide range of genetics problems; you may need to adjust the *order* in which you work through the steps according to the information given in the question.

1 Read the question and make sure that you understand all of the terms that are used (e.g. pure-breeding, heterozygous, etc.).

2 Draw out the crosses as mating diagrams, using one of the two alternative layouts shown in Figures 8.8 and 8.9 in the book, and include all the information that is given in the question, e.g. pure-breeding tells you that a variety is homozygous. This will help you to think about the problem logically, and show what information you need to deduce, e.g. the genotypes of one or more of the generations involved.

3 Assign letters to the alleles of the genes, or the copies of genes, that are involved, if they are not specified in the question. You may need to use information provided in the question to deduce which phenotype is dominant and which is recessive; for example, if a particular phenotype disappears in the progeny of one generation and reappears in the next generation, you can infer that this phenotype is recessive to the phenotype that is masking its presence.

4 Complete the mating diagram; for example, use the genotypes of each generation to deduce the genotypes of the gametes, and use the genotypes of the gametes to determine the genotypes of the offspring. (With some problems you may be working from genotypes of offspring back to the genotypes of the parents.)

5 Use information about the dominant allele or character to determine the phenotypes of each generation. (In some problems, such as the one given here, you will start by using phenotypes to determine genotypes.)

6 Calculate the ratios of the genotypes and of the phenotypes from the mating diagram.

7 Ask yourself whether the results are consistent with what you have learned about genetics and probability.

We suggest that you tackle the following problem using the above guidelines.

A genetics problem

The fruit-fly *Drosophila melanogaster* is widely used by geneticists for breeding experiments in the laboratory because it is easy and cheap to rear and each female produces hundreds of eggs. Suppose that you carry out a breeding experiment using two pure-breeding varieties of *D. melanogaster*, one with normal-shaped eyes and one with eyes reduced to about half the normal size, called 'eye-less'. The first cross is between these two varieties. The F_1 offspring all have normal eyes. The second cross is between an F_1 normal-eyed fruit-fly and a pure-breeding eye-less variety. What is the expected ratio of genotypes, and the expected ratio of phenotypes of the offspring of the second cross?

Activity 8.3 The 3 : 1 phenotypic ratio

(The estimated time for this activity is 30 minutes.)

This activity is designed to consolidate your understanding of ratios, fractions and probability. It takes the form of a series of very short questions. Try to answer all of the questions before looking at the answers given in the comments. The comments also contain some general advice on ratios and fractions.

(a) Count the purple and the white grains (yellow in this dried cob) on the one visible side of the F_2 cob in Figure 8.13. Calculate the ratio of purple to white grains, expressing your answer in the way shown in the right-hand column of Table 8.2.

(b) Write your results down in the appropriate columns in Table 8.2 in the book. (Space has been left at the bottom of the table for you to do this.) How do your results compare with our results given in Table 8.2?

(c) The grains on the cob are the result of fertilizations between two kinds of pollen grains, *G*-bearing and *g*-bearing, and two kinds of ovules, *G*-bearing and *g*-bearing. Thus the expected phenotypic ratio is three dominant (purple) : one recessive (white). Explain the deviation from the 3 : 1 ratio for the part cob that you counted.

(d) Now think again about the grains you counted. How many grains are visible altogether? Give the number of white grains as a fraction of the total number of visible grains.

(e) What is the probability that an F_2 maize grain will have the genotype *g g*? Compare this with your answer to part (d).

(f) Compare your answers to part (a) and part (d). Are these answers consistent? How do your answers relate to what you have learnt about fractions and ratios previously in S103?

Activity 8.4 Mitosis, meiosis and recombination

(The study time allocated to this activity is 1¾ hours.)

This DVD-multimedia activity is important because, for the most part, it contains new material that is not presented in the book. You should study it before embarking on Section 9 of the book.

The activity begins by revising the nuclear division of mitosis (Block 4, Section 3.3), which results in the production of two identical progeny cells. An understanding of the sequence of nuclear events and the physical structures involved in mitosis is a necessary background for the next part of the activity, in which you will study the nuclear division of meiosis and the production of haploid gamete cells. You will revise the segregation of alleles, which follows from the behaviour of chromosomes at meiosis.

The behaviour of chromosomes at meiosis is also important for understanding the patterns of inheritance when more than one pair of contrasting characters are observed simultaneously. During meiosis, genes and alleles are shuffled and this results in the production of gametes with new combinations of alleles.

This activity ends by looking at maps of the order of genes along a chromosome.

'Mitosis, meiosis and recombination' is on the Block 9 DVD. You should start this activity now.

Activity 9.1 Sources of phenotypic variation

(The estimated time for this activity is 20 minutes, divided into a number of chunks. However, if you do the activity whilst reading the related text, it will take very little time.)

In Section 8 you learnt about some sources of phenotypic variation. In Section 9 you will meet a number of other factors that contribute to the variation between individuals. Keeping a summary of these sources of variation will be useful for reference at a later date — for example, when you study Section 13, which deals with evolution, a process that cannot proceed without variation. When producing a summary that will be used for reference or revision purposes you need to think about how to present it — as a list, a set of notes, a table or a summary diagram — as well as how much detail to write in order to be able to recall the important points. You have already completed a summary diagram and produced a flow diagram to aid your revision of Section 5 (Activities 5.1 and 5.2).

The sources of phenotypic variation introduced in Section 8 were important, so you should begin your summary with these. Do this now by looking back at the summary of Section 8 and identifying each of the sources of phenotypic variation. Then check your list with the list in the comments on this activity before you continue with Section 9. It is a good idea to add to your summary after completing each subsection.

At the end of each of Sections 9.1–9.5

If you have not already done so, add to your summary any new source of phenotypic variation that you identified in this section. You may need to refer back to the book to help you with this.

At the end of Section 9.6

Add to your summary any new source of phenotypic variation that you identified in this section. Then read about the more general issues relating to revision at the end of the comments on this activity.

Activity 9.2 Applying genetic principles to sex-linked genes

In this activity you will follow the inheritance of a sex-linked gene. T. H. Morgan, working in New York, USA, carried out investigations on *D. melanogaster* for which he was awarded a Nobel Prize in 1934. He noticed a white-eyed male fly in his stock of normal red-eyed flies. He mated this white-eyed male with a red-eyed female and all the F_1 offspring had red eyes. (There are a number of different genes that influence eye colour in *D. melanogaster*, and we now know that the gene Morgan investigated is different from the one that has an allele that produces brown eyes.)

From this we can conclude that red eye is dominant to white eye, so we can represent the normal allele as R (red-eyed) and the recessive allele as r (white-eyed). These observations in themselves are not unusual. When red-eyed F_1 males were mated with red-eyed F_1 females, the F_2 generation contained about 3 000 red-eyed flies and about 1 000 white-eyed flies. This result again may not appear to be striking since the ratio is 3 : 1, and this is consistent with breeding experiments in which the original parents were both pure-breeding for eye colour. However, Morgan made a crucial discovery: all the F_2 white-eyed flies were males!

(a) To understand these results, complete the diagram on the next page, which is a summary of Morgan's observations. To help you with this, use the guidelines for tackling problems in genetics given in the notes to Activity 8.2. However, the mating diagram has already been drawn for you and letters have been assigned to alleles. Note that each of the gene copies for eye colour is shown on the appropriate sex chromosome, denoted by the letter X or Y; you will find it helpful to use this notation when completing the diagram.

(b) What are the possible phenotype, for both sex and eye colour, of the F_2 flies, and what are their expected ratios?

(c) Explain, in one sentence, why the incidence of phenotypes for recessive sex-linked characters is much higher in males than in females.

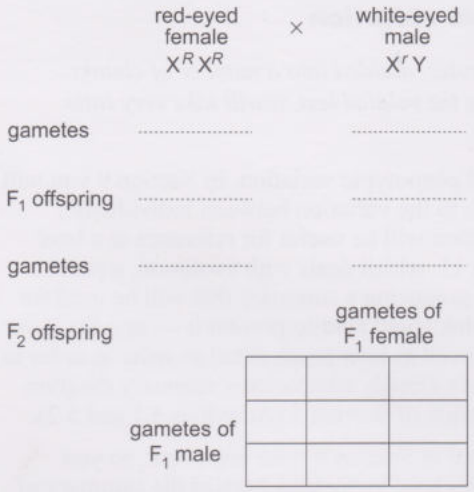


Figure 9.2.1 The breeding experiment that led to the identification of a linkage between eye colour and the sex of the fruit-fly, *D. melanogaster*.

Activity 9.3 Applying existing knowledge of genetic principles to multiple alleles

Human ABO blood groups can be assigned to one of four phenotypes, which are determined by pair-wise combinations of three alleles *A*, *B* and *O*. The relationship between the phenotypes and the six possible genotypes is shown in Table 9.3.1.

Table 9.3.1 The genetic basis of ABO blood groups in humans.

Genotype	Phenotype (blood group)	Genotype	Phenotype (blood group)
AA	A	*BB*	B
AO	A	*BO*	B
AB	AB	*OO*	O

(a) What is the dominance relationship between allele *O* and each of alleles *A* and *B*?

(b) Comment on the dominance relationship between alleles *A* and *B*.

(c) Using the guidelines for solving problems in genetics given in the notes for Activity 8.2, determine the possible phenotypes and genotypes of the children produced by two individuals, one of blood group AB and the other of blood group O. Compare the phenotypes of the children with those of the parents.

Activity 10.1 Revision: structure of biopolymers

(The estimated time for this activity is 45 minutes.)

This activity revises information from Section 3, and involves representing this information in a different way. In addition, it is designed to improve your writing skills (see also Activities 3.3 and 8.1). The emphasis here is on presenting your answer in the way that the question requires, and on being critical of your own work.

(a) Write a paragraph, of no more than 200 words, in answer to the following question:

> What are the features common to the three main groups of biopolymers: proteins, polysaccharides and nucleic acids? *(20 marks)*

Your answer should be based on information in Sections 3.2–3.5. Illustrate your answer, where possible, with specific examples, and with diagrams that show the overall structure of biopolymers rather than individual component parts. To save time, rather than drawing the diagrams, choose which figure in the book you would include in your paragraph.

You should complete your answer before reading part (b).

(b) Now mark your answer, using the following mark scheme for guidance:

Science content

The following **five** key points should be awarded two marks each:

(i) Molecules of all three biopolymers are large. *2 marks*

(ii) Each biopolymer is composed of repeat monomers: amino acids for proteins, monosaccharides, or sugars, for polysaccharides, and nucleotides for nucleic acids. *2 marks*

(iii) Each monomer is linked to adjacent monomers by covalent bonds formed by condensation reactions with loss of water. *2 marks*

(iv) The higher-order structure is maintained by weak bonds. *2 marks*

(v) The structure of each biopolymer is closely related to the function it performs. *2 marks*

Diagrams

Award four marks for diagrams (one for each diagram) placed at appropriate positions in the text, as long as each is referred to in the account, has a title, is labelled and illustrates the points referred to in the text. *4 marks*

Any of the following would be appropriate: Figure 3.3 (shape of fibrous protein, collagen); Figure 3.5 (globular protein, myoglobin); other figures that illustrate the shape of globular proteins and would also be acceptable, e.g. Figure 3.6a (receptor protein), Figure 3.6b (enzyme), Figure 3.7 (antibody); figures showing shapes of polysaccharides, e.g. Figure 3.12b (amylopectin, branched); Figure 3.12a (cellulose, unbranched).

Writing

Award two marks for each of the following three aspects:

(i) clarity of writing — deduct one mark for each ambiguity. *2 marks*

(ii) conciseness — deduct one mark for each irrelevant point, and if the account is still overlength once these points are removed, then deduct one mark for each 30 words over the 200 word limit. *2 marks*

(iii) coherence — the five key points should be dealt with one at a time. One logical sequence is as presented in the order above, but other sequences are possible (e.g. (i) and (ii) could easily be reversed, and (v) could come first). *2 marks*

Total marks

Any student who tackles the account by writing about each biopolymer in turn, rather than each key feature in turn, should be awarded a maximum of 14 marks, i.e. they should not be awarded any marks for presentation. **20 marks**

Activity 10.2 Understanding DNA replication

(The estimated time for this activity is 30 minutes.)

This activity will help you consolidate your understanding of DNA replication. In addition, it is the fourth activity in the series designed to help you to improve your answers to assignment questions (see Activities 3.3, 8.1 and 10.1). Here we ask you to be critical of the writing of others; you are *not* asked to do the writing yourself.

Imagine that at this point in Block 9 students studying S103 had been given the following question:

> Write a paragraph of no more than 150 words summarizing the process of DNA replication. Include a diagram in your answer.

Compare the two student answers given below, noting down what is good and poor about each, in terms of science content, writing style and how well each answer fits the question set.

Answer 1

> During DNA replication, a DNA double helix unwinds and each single polynucleotide strand forms a template. On which a new strand is synthesized. DNA polymerase adds nucleotides and the base-pairing rules. G binds C, T binds A and vice versa. The sugar–phosphate backbone of the DNA molecule is formed. Two identical helices are thereby synthesizer. This is conservative replication because each new double helix contains one polynucleotide strand from the 'parent' molecule and one newly synthesized strand. *(79 words)*

[*No diagram*]

Answer 2

DNA replication is a conservative process by which one molecule is copied to give two. The two DNA strands are made up of nucleotides. These unwind and base-pairing occurs. G binds to A and vice versa, T binds to C and vice versa as shown in Figure 10.2.1. (*49 words*)

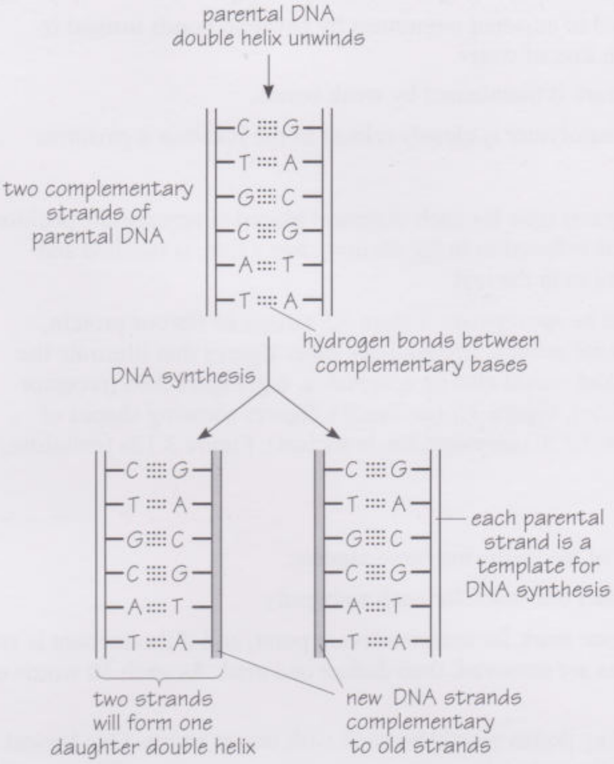

parental DNA
double helix unwinds
two complementary strands of parental DNA
C G
T A
G C
C G
A T
T A
hydrogen bonds between complementary bases
DNA synthesis
each parental strand is a template for DNA synthesis
two strands will form one daughter double helix
new DNA strands complementary to old strands

Figure 10.2.1 The process of DNA replication.

Activity 11.1 The flow of information from DNA to RNA to polypeptide

(The estimated time for this activity is 15 minutes.)

This activity will help to consolidate your understanding of the processes of transcription and translation. In addition, it is the fifth activity designed to improve your answers to assignment questions.

In this activity you are not required to write an answer, but rather to carry out the planning that would be required in order to write an answer to the following question:

> Write an account, which would be suitable for revision purposes, that summarizes in about 300 words the processes of transcription and translation. A description of the genetic code, and of the structure of DNA and RNA, is not required.

Identify the key scientific points relating to these two molecular processes and put them in a logical order, which could then be used as the basis for putting together an answer.

The comments on this activity include a list of key points, one possible correct answer, and an indication of what you should have achieved from carrying out this activity.

Activity 11.2 A foretaste of the genetic code

(The estimated time for this activity is 15 minutes.)

It is possible to complete this activity about the genetic code from the information already provided, but you may find it quite challenging! Try it now, but do not worry if you cannot complete the activity — it will be more straightforward after you have studied Section 11.5, and you could return to it then.

Below is a short sequence of part of a DNA template strand:

TACCCTCCTCAATTCGGA

(a) Copy out this DNA sequence, and then write below it the RNA sequence that would result from its transcription. (You may wish to look at the base-pairing rules for transcription in Table 11.1 of the book.)

(b) The RNA sequence that you have just produced should have 18 bases in it, which can be split up into 6 codons. Draw lines between each of the codons to separate them clearly.

(c) From Figure 11.8 in the book you should be able to identify the amino acids that correspond to six different mRNA codons. You may find it helpful to list the codons with their corresponding amino acids. (It will be easier to use the abbreviated names, as given in Figure 11.8.) Then compare these codons with those from (b) above. From this you should be able to write out the amino acid sequence that the six codons in (b) would produce after translation.

Activity 11.3 The genetic code

(The estimated time for this activity is 15 minutes.)

Below is the start of the base sequence in the template strand of a section of a DNA molecule isolated from a particular population of cells:

TACCTCGGTCATCCCT…

Use the information given in Tables 11.1 and 11.2 in the book to answer the following questions:

(a) If the above sequence is transcribed, what will be the corresponding mRNA base sequence?

(b) If the mRNA sequence is translated, what will be the amino acid sequence of the product?

(c) Write out the corresponding DNA sequence of the non-template strand.

(d) If this non-template DNA sequence could be transcribed, what would be the corresponding mRNA sequence?

(e) If this mRNA could be translated, what would be the amino acid sequence of the product?

(f) In practice, why would the sequence you wrote out in answer to (d) not be translated? *Hint:* what is missing from this sequence that appeared in the answer to (a)?

Activity 11.4 Information flow in cells

(The estimated time for this activity is 35 minutes.)

This DVD-video sequence illustrates the key points of Sections 10 and 11. It concentrates on the flow of information from DNA to RNA to polypeptide, showing the relationship between the sequence of bases in DNA and the sequence of amino acids in a polypeptide chain. No new concepts are introduced in the sequence but by animating the processes involved it helps to bring them alive.

You will find it helpful to have the following summary to hand whilst watching the DVD-video, pausing after each point to check that you have understood and to add details in the 'Comments' column.

Summary	Comments
(1) *Introduction* The three key features of DNA are: the molecule is stable; it can be faithfully replicated; and it contains coded information which is used to direct the synthesis of proteins.	
(2) *DNA structure* The basic building blocks of DNA, the nucleotides, are linked to form polynucleotide chains. The precise base-pairing rules form the basis of the double-helical structure of DNA.	
(3) *DNA replication* A DNA double helix unwinds and each polynucleotide chain forms a template for DNA replication. Free nucleotides are added sequentially, according to the base-pairing rules. Two daughter DNA double helices are produced, each identical to the original.	
(4) *The information in DNA* This is coded within the base sequence and composed of the four-letter language of A, G, C, T. One particular sequence of bases is equivalent to one gene.	
(5) *Gene to polypeptide* In the flow of information from DNA to polypeptide, first an mRNA strand is synthesized with a base sequence complementary to the template strand of the appropriate gene — a process called transcription. The information in mRNA is translated into the sequence of amino acids in a polypeptide chain.	
(6) *RNA structure* RNA is a single polynucleotide chain; it contains ribose instead of the deoxyribose; and the base U replaces T.	
(7) *Transcription — writing the message* A section of DNA unwinds and the message, mRNA, is produced by transcription on the template strand.	
(8) *Translation — reading the message* A tRNA molecule, carrying its specific amino acid, binds to the mRNA codon via the anticodon. A second tRNA molecule binds to the mRNA and the two amino acids become joined by a peptide bond. The process repeats, elongating the polypeptide chain until the stop codon is reached.	
(9) *At the ribosome* Translation begins when mRNA binds to a ribosome. The process continues as the ribosome moves along the mRNA one codon at a time, until a stop codon is reached. The completed polypeptide chain is released from the ribosome.	

Activity 11.5 Mutation and the polypeptide sequence

(The estimated time for this activity is 15 minutes.)

As well as changes in the sequence of bases, a mutation sometimes may involve the omission of a base or the insertion of an extra base. In this activity we will look at the consequences of such changes starting with the same DNA sequence as in Activity 11.3.

(a) A population of cells has been treated with a chemical agent which has brought about a change in the DNA sequence. This is very specific, such that the sixth base in that sequence is deleted, shown here underlined:

TACCTCGGTCATCCCT…

The new template sequence is as follows:

TACCTGGTCATCCCT…

Use Table 11.2 in the book to work out the effect this change will have on the amino acid sequence if this DNA sequence is transcribed and the RNA product translated. What is the significance of this result?

(b) Another population of the same type of cells as used in (a) has been treated with a different chemical agent, which results in a different kind of mutation. This time an extra base is added to the DNA, such that the template sequence, with the inserted base shown underlined, now reads as follows:

TACCCTCGGTCATCCCT…

What effect will this have on the corresponding amino acid sequence? What is the significance of the result you have obtained?

Activity 12.1 Genomes and gene function

In this activity you will compare genomes and gene function in prokaryotes and eukaryotes by completing Table 12.1.1. Try to complete the table without looking at the book, by adding an appropriate single word, such as 'present' or 'absent', or the name of a site, such as 'cytosol' or 'nucleus', to the blank space in each column opposite each feature. Then refer back to the book and amend/complete your table.

Table 12.1.1 Comparison of genomes and gene function in prokaryotes and eukaryotes.

Feature	Prokaryotes	Eukaryotes
genome complexity		
site of DNA replication		
site of transcription		
site of translation (ribosomes)		
introns		
exons		
split genes		
repeat sequences		
mRNA splicing		

Activity 13.1 Revision: evolution by natural selection

This activity revises the main principles of evolution discussed in Block 4, and of the relevant genetics described in this block. Complete the two paragraphs below about evolution and natural selection, by writing the appropriate word or phrase, chosen from the following list, in the spaces provided. Some words/phrases should be used more than once. Then check back to Block 4, Sections 9–11, and Sections 8 and 9 of this block, and amend/complete your answer as appropriate.

Missing words or phrases: population; phenotype(s)/phenotypic; genetic drift; polymorphic; fitness; relative frequencies; mutation(s); heritable; struggle for existence; genetic variation.

Over time, each generation of organisms is replaced by a new generation. For any particular character, if all the individuals have identical ________________, then this process of replacement has no effect. However, many characters are ________________, that is, they exist in two or more alternative forms. These forms may change in their ________________ between generations, by one of two principal mechanisms of evolutionary change: ________________, whereby a character may increase or decrease in frequency due to chance events; and natural selection, whereby some characters are more likely to survive than others. ________________ provide the raw materials on which ________________ and natural selection can act.

The essence of Darwin's theory is that natural selection will operate if three fundamental criteria are met. First, individuals within a ________________ must show ________________ variation. Second, some of this ________________ variation must be due to ________________ and hence have a ________________ basis. Third, there is a ________________ so that, on average, more or fewer individuals of one ________________ must survive than those of another. Natural selection favours the ________________ (e.g. brightly coloured male guppies) that results in most offspring surviving to maturity. ________________ is the numerical measure of relative reproductive success.